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Epidemiology and Mechanisms of Allergic Reactions to Grass Pollen

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Abstract

The purpose of the study was to investigate grass pollen allergy to gain a better understanding of its manifestations, diagnosis, prevention, and treatment. A comprehensive review of the relevant literature was conducted using academic databases to gather existing knowledge on the topic. Results revealed that about 40% of patients in Europe are allergic to pollen, and more of them are sensitive to grass pollen. The most common allergens in Europe are pollen from grasses, birch, and ragweed. Symptoms caused by these allergens include sneezing, difficulty breathing due to swelling of the nasal mucosa, itching in the nose and eyes, runny nose, sore throat, drowsiness, general weakness, decreased attention, headaches, cough with shortness of breath or wheezing. The most important allergens of grass pollen are the molecules of perennial timothy's Phl p 1, Phl p 4, and Phl p 5. Of these, Phl p 1 is the most common allergen, which plays an important diagnostic role. Green spaces can have a protective effect on the severity of allergic symptoms. Air pollution, on the contrary, is associated with an aggravation of allergy symptoms. In Poland, where urbanization and air pollution are urgent problems, this can exacerbate the situation with allergic manifestations to grass pollen. Thunderstorm asthma posed a serious threat to people with pollen allergies, especially in the spring and summer, when grass pollen levels are particularly high. Grass pollen plays an important role in exacerbating childhood asthma and can cause repeated hospitalizations in pediatric departments. Allergen immunotherapy remains the only treatment for allergic rhinitis and asthma that can alter the course of the disease. In Poland, allergy to grass pollen is common, so subcutaneous and sublingual immunotherapy can be used for long-term control of allergic symptoms. However, patient adherence to long-term therapy remains a problem, as in other countries.

Keywords

Rhinitis; Asthma; Diagnosis; Immunoglobulin; Nasal Provocation

Introduction

Allergy to grasses is a significant problem in the medical field and society, affecting the quality of life of a large number of people. The reasons for the growing number of patients with allergies to grasses are global warming and the variability of the rainy season, which can prolong the flowering season and increase the concentration of pollen in the environment. In addition, air pollution, urbanisation, and changing land use can increase an allergic reaction to pollen.

Due to insufficient awareness and knowledge regarding the symptoms and preventive measures for grass pollen allergy, diagnosis is often delayed (Lyubchyk *et al*., 2019; Yermukhanova *et al*., 2022). This results in postponed treatment, worsening of symptoms, the development of complications, and a significant decline in health, well-being, and overall quality of life. In addition, conventional methods of treatment often have insufficient effects. Some patients may have contraindications or side effects to the use of conventional treatment. And immunotherapy is not always available; besides, it requires a long therapeutic process. Consequently, researchers across the globe have explored various aspects of grass pollen allergy to enhance understanding and improve management strategies.

This topic was studied by the following researchers: Lipiec *et al*. (2019), Kiotseridis *et al*. (2013). According to them, allergy to grass pollen affects from 10% to 30% of children, causing mainly seasonal allergic rhinitis and other symptoms. The grass and its pollen cause a large number of symptoms of allergic conditions in late spring, starting in April, and in summer, starting in June (Zubtsova and Skliar, 2023). However, in warmer regions, its registration is carried out all year round. In addition, this condition may intersect with the flowering of trees and weeds.

In four Polish cities, the frequency of detection of allergic rhinitis and bronchial asthma was estimated depending on the amount of pollen (Lipiec *et al*., 2019). Of the 2,255 participants, periodic allergic rhinitis was detected in almost 300 patients, and a poorly controlled form of rhinitis was detected in 338 patients. Among adults, allergy symptoms that occurred during the flowering of grass pollen were noted to a greater extent in Wroclaw, 18.4%, the lowest degree was recorded in Bialystok, which was recorded in 13.5% of patients, and in Katowice, this indicator was observed in 14.0%. There were no differences in the two age categories of children. Asthma symptoms for the 6-7-year-old group were registered in Bialystok, which was 0.8%, in Katowice, the indicator was recorded in 1.4%, with the highest percentage in Wroclaw – 3.2%. For the 13-14-year-old group, asthma was found with the lowest rates in Bialystok, which was noted in 1.4%, and the highest percentage in Warsaw, which reached 4.3%. Adults most often reported asthma in Wroclaw – 3.7%, less often in Bialystok – 1.0%.

The relationship between the amount of pollen and the occurrence of symptoms such as rhinitis, conjunctivitis, broncho broncho-obstructive syndrome was evaluated by Kiotseridis *et al*. (2013). Of the 98 participants, 89 patients completed the study. It was found that rhinitis symptoms occurred at 0-30 grains/m^3, after which they increased faster to 80 grains/m^3. Ocular symptoms increased at values of 70 grains/m^3 and continued to increase to 140-150 grains/m^3. Pulmonary symptoms did not significantly

worsen up to 50 grains/m^3, but over 70 grains/$m^{3,}$ the increase was gradual. An assessment of the severity of symptoms showed that the maximum values of allergy manifestations ranged from 7 to 8 points. From day 8 to 28, symptoms were estimated at 8-9 points when the maximum concentration of grass pollen was noted, followed by a decrease by the end of the study when pollen levels decreased.

Bastl *et al*. (2021) noted that the greatest severity of symptoms in patients with pollen allergy was observed in patients in the second phase of the pollen season, which was 70%, and was caused mainly by *Arrhenathérum* (Oat-grass), *Festuca* (Fescue), and *Lólium* (Ryegrass). Then the first phase was noted – the registration of symptoms of which was 20%, caused by *Póa Triviális* (Rough bluegrass) and *Dáctylis* (Cocksfoot grasses). And the lowest severity of symptoms was recorded in the third phase, 10%, which depended on *Phleum* (Timothy) and *Cynodon* (Bermuda grass).

The study by Polish researchers and Wagner *et al*. (2022) assessed the degree of sensitisation to spices in patients with allergies to grass pollen and other aeroallergens. They found that out of 180 patients, 29% of the cases had a positive reaction to a skin test for spices and herbal pollen extracts. Pollinosis significantly increased the risk of a skin test reaction to spices among adults and children. The degree of reactions of the skin tests to spices had a high dependence on the reactions of the skin test to the pollen of grasses in children.

According to the estimates of Ramon *et al*. (2019), sensitisation to the subfamily *Pooideae* (Cool-Season grasses) covered 86.8% of 894 patients. Positive reactions to the subfamilies *Chlorideae* (Cotton bollworm) and *Panicoideae* showed a smaller size of skin tests compared to *Pooideae.* The proportion of patients diagnosed with bronchial asthma accounted for 46.9% of cases, while rhinoconjunctivitis was observed in 22.6% of cases. Notably, sensitisation to *Festuca arundinacea* (Tall fescue) at 0.074 and *Paspalum notatum* (Bahiagrass) at 0.070, in the presence of conjunctivitis, emerged as statistically significant indicators.

The study on the effectiveness of allergenic immunotherapy in elderly patients with allergies to grasses was conducted by Bozek, Cudak and Walter Canonica (2020). The researchers observed the effect after a 3-year course of injectable specific immunotherapy in elderly patients with allergic rhinitis to grasses. After immunotherapy, the combined symptom index decreased from an average of 2.15 to 1.13 and remained lower than in the control group for 3 years after therapy. Specific immunoglobulin E (SiGe) to grass pollen increased during immunotherapy and remained at a high level during 3 years of follow-up. The negative aspects affecting the quality of life significantly decreased from 1.51 to 1.01 and decreased to 0.97 during the observation period.

The use of polyvalent mechanical bacterial lysates in allergy to grass pollen in children was investigated by Janeczek *et al*. (2021). The severity of rhinitis symptoms, peak inhalation through the nose, smears from the nasal cavity with the determination of eosinophils, and nasal flushes to determine allergen-specific IgE to timothy pollen were evaluated. It has been determined that significant effectiveness in reducing the symptoms

of seasonal allergic rhinitis can be achieved using sublingual polyvalent mechanical bacterial lysates.

The purpose of the study was to examine the manifestations of allergy to grass pollen and to explore approaches to its diagnosis, treatment, and prevention. The objectives were to enhance knowledge about pollen allergies, improve understanding of the underlying processes, and evaluate diagnostic methods and therapeutic interventions.

Methodology

The study involved evidence-based information, which was published in reliable medical journals and databases. Questions about allergy to grass pollen were investigated, which included symptoms and manifestations, prevalence and allergens, diagnostic methods, therapeutic measures, and prevention. The paper considered the general characteristics of this allergenic group, the use of plants in everyday life, and the prevalence of the most significant grasses that cause allergic reactions in humans. In addition, the prevalence of allergy to grass pollen among the European population was also investigated. The symptoms caused by grass pollen were considered, as well as diagnoses that were established by doctors. Data on changes in climatic and weather conditions were also of great importance in conducting this study. Plant allergens, diagnosis, and treatment, which included sublingual and subcutaneous immunotherapy, were studied.

The search for materials was carried out over the last 5 years, 2020-2024. The research design included systematic reviews, informational and literary reviews, studies with clinical cases, and practical information. Studies with relevant and valuable information, but with a publication date earlier than 2020, were also included in the list of references. The information was searched using the following keywords: prevalence of allergy to grass pollen, allergy to grass pollen, allergy to grasses, allergic rhinitis to grass pollen, bronchial asthma to grass pollen, conjunctivitis to grass pollen, urticaria to grass pollen, anaphylaxis to grass pollen, allergy to *Elymus*, allergy to *Festuca* (Fescue), *Poa* (Rough bluegrass), *Stipa* (Feather grass), *Calamagrostis* (Reed grass), *Eragrostis* (Lovegrass), diagnosis of allergy to grass pollen, immunoglobulin E, specific immunoglobulin E, IgE, plant allergens, prevalence of allergy to plants, Poland, treatment of allergy to plants, sublingual immunotherapy, subcutaneous immunotherapy, oral immunotherapy, specific immunotherapy of allergy to herbs, pollinosis, herbal pollen, pollen season, sensitisation to grass pollen, sensitivity to grass pollen, immune response to plants, allergic reaction to grass pollen, epidemiology of pollinosis, analysis of grass allergens, allergic tests for grass pollen, allergic conditions to grass pollen in children, allergy to grass pollen in adults, genetics of pollen allergy, prevention of allergy to grass pollen, allergenic properties of grass pollen.

The literature search strategy was guided by defined inclusion and exclusion criteria to enhance methodological transparency. Studies were included if they (i) were published in English, (ii) provided open access for full-text reading, (iii) were retrievable via keyword-based searches, and (iv) contained clear bibliographic metadata, including publication date, first author, journal title, and country of origin. Searches were conducted across four databases: PubMed, Scopus, Google Scholar, and ScienceDirect.

Studies were excluded if they exhibited incomplete indexing, lacked adequate abstracts or methodological clarity, or fell outside the thematic scope of grass pollen allergy research. Older studies published before 2020 were included only when they contributed essential background or foundational data not replicated in recent literature. After reviewing 103 initially identified studies, 45 met the final eligibility criteria and were included in the analysis (Figure 1).

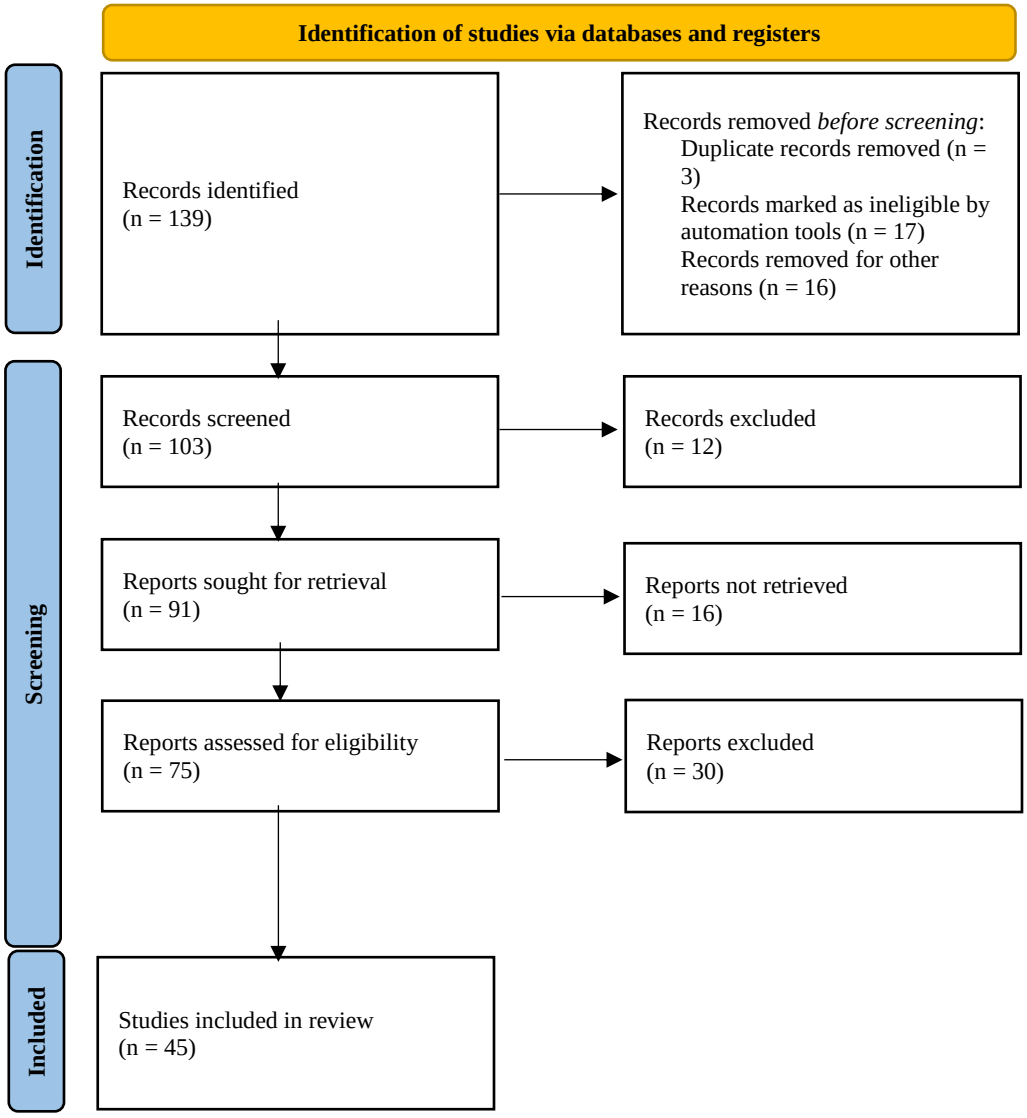

Figure 1: PRISMA 2020 flow diagram for new systematic reviews

Results and Discussion

Poaceae (Grasses) are a widespread family of plants that are part of a variety of ecosystems that are found on all continents. Grasses are a major part of many ecosystems and sources of food for a large number of species, which enhances the prevalence and

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dominance of grasses over other plants. In many cultures, the use of plants covers 40% of human nutritional needs in the form of eating wheat, corn, and rice. Grasses are also needed for grazing and harvesting hay, and silage.

In addition to the benefits of nutrition for humans and animals, grasses have negative sides, such as allergies (García-Juárez *et al*., 2024; Uazhanova *et al*., 2018). Approximately 40% of European residents have various symptoms of pollen allergy, and a large number have allergic manifestations specifically to grass pollen (Janeczek *et al*, 2021). But not all plants can cause the same symptoms in a patient, since different species have different conditions, which are reduced to environmental, biological, and genetic factors (Jung *et al*., 2021). The study of which pollen of specific grasses is in what quantities in the air, which species are most allergenic to humans, and the time intervals of flowering of grasses is poorly understood. The classification and quantification of pollen from different species of the family *Poaceae* have inaccuracies, but the development of new molecular methods and innovative methods of aerobiology and ecology helps to understand the topic of pollen allergy (Campbell *et al*., 2023; Jung *et al*., 2021; Oteros *et al*., 2020).

There are about 11 thousand species of *Poaceae* plants, which makes it the fifth most widespread family among all plants (Bouchenak-Khelladi *et al*., 2010). The global distribution of grasses varies depending on the distance to the poles and the habitat (Zubtsova *et al*., 2019; Zymaroieva *et al*., 2021). A subtropical area is more likely to have a greater variety of species. The frequency of occurrence of the most common grasses is shown in table 1.

Table 1: Distribution of the most common grasses on various continents

Taxa	*Europe*	*Africa*	*Asia Temperate*	*Asia (Tropical)*	*Australasia*	*Pacific*	*America (Northern*	*America (Southern)*	*Antarctic*	*Total*
Festuca	192	67	158	49	19	8	62	163	5	621
Poa	54	29	158	96	84	7	80	120	10	496
Panicum	6	175	27	42	40	26	108	198	0	463
Eragrostis	10	212	51	56	75	33	53	91	0	401
Stipa	47	20	133	30	67	1	38	76	0	348
Paspalum	4	11	17	14	19	15	96	290	1	326
Aristida	1	70	23	25	59	5	50	100	0	284
Calamagrostis	15	2	80	31	40	2	38	99	1	266
Digitaria	4	112	31	56	47	21	37	81	1	263
Elymus	25	9	173	30	15	1	41	10	2	241
Sum (#)	358	707	851	429	465	119	603	1.228	20	3.709
Total (#)	945	2.595	2.991	2.187	1.566	437	1.779	3.257	85	11.313
Sum (%)	37.88%	27.24%	28.45%	19.62%	29.69%	27.23%	33.90%	37.70%	23.53%	32.79%

Source: Frisk, Adams-Groom and Smith (2023)

Allergy to grass pollen covers about 10-20% of the world's population (Global Atlas of Allergy, 2014). Pollen from grass, *Betula* (Birch), and *Ambrosia* (Ragweed) are the most common causes of pollen allergy worldwide (Global Atlas of Allergy, 2014; Newson *et al*., 2014). Symptoms caused by allergenic pollen include sneezing, rhinorrhoea, difficulty breathing due to swelling of the nasal mucosa, itching in the nose and eyes, itching in the throat, cough with difficulty breathing, sometimes shortness of breath with

wheezing, drowsiness, general weakness, decreased attention, headaches (Prontenko *et al*., 2019). Pollen can also cause the development of bronchial asthma and its complications, in case of delayed diagnosis and treatment. Allergic rhinitis causes not only poor human well-being, but also reduces performance, quality of life, and affects the productivity of the entire society (Shuvar *et al*., 2021). The additional influence of air pollution complicates problems with allergic manifestations, since this factor worsens the manifestations of bronchial asthma (Komilova *et al*., 2023; Bachtaev *et al*., 2017). In addition, air pollution contributes to the modulation of allergen activity and the immune system's response to the effects of allergies.

It is expected that with climate change, the severity of allergic reactions to grass pollen and cases of bronchial asthma will increase (Iwanycki Ahlstrand, Elvery and Primack, 2023). The main problem is that standard pollen monitoring methods cannot accurately identify different types of grasses, combining them into one category, even though their flowering periods and allergenic activity vary greatly. Maximum pollen concentrations also occur earlier in the season. Herbarium samples collected over almost 200 years and pollen tracking data over the past 40 years have shown that many species of grasses, such as *Poa pratensis* (Kentucky bluegrass), *Dactylis glomerata* (Orchard grass), *Festuca rubra* (Red fescue), and *Holcus lanatus* (Yorkshire fog), have optimised their flowering time in response to warmer spring temperatures (Iwanycki Ahlstrand, Elvery and Primack, 2023). These species are the main sources of pollen, which causes the greatest allergic reactions. The use of herbarium data helps to accurately determine which types of grasses are responsible for peak pollen loads in different periods. This is important for predicting allergic risks and developing more accurate monitoring methods. Based on these data, it is possible to improve the forecasts of pollen allergy in people with asthma, both in current climatic conditions and in the future, considering global changes.

Analysis of grass pollen revealed that allergens of different species varied in biochemical properties, including proteins and lipids, which influenced their allergenicity (Allergen Encyclopedia, 2024). These allergens were classified into genera and species based on their biochemical functionality. A total of 13 main allergenic groups were identified, among which two groups caused the greatest allergic reactions in 65-90% of patients (Aud-In, Somkid and Songnuan, 2019).

The main allergens of grass pollen are molecules belonging to the subfamily *Pooideae*, in particular to the common timothy (*Phleum pratense* Phl p) (Mendy and Zeldin, 2020). To date, 13 Timothy's molecules have been described, among which the most significant are Phl p 1, Phl p 4, and Phl p 5. Of these, the allergen Phl p 1 is the most common, which belongs to group 1. During the tests for allergy to common timothy, Phl p 1 is determined in almost 100% of patients. Phl p 4 is an allergenic protein that cross-reacts with carbohydrate determinants (CCD). Phl p 4 is characterised by a high frequency of IgE reaction, but its allergenicity is considered low, since IgE antibodies produced in sensitised people are directed against insignificant antigenic CCDs. Phl p 5: This allergen has significant activity and consists of two domains, which lead to the activation of high levels of IgE in patients. Phl p 5 has significant allergenic potential. The remaining allergen proteins of this plant are either minor allergens (Phl p 2, Phl p 6, and Phl p 11) or are non-specific cross allergens (Phl p 7 and Phl p 12) (Table 2).

Table 2: Chemical names, functions, and positive IgE for Phl p molecules of timothy grass pollen

Timothy grass	*Chemical name*	*Function*	*IgE positivity*
Major specific allergens			
Phl p 1	CCD-bearing protein	Beta-expansin	95%
Phl p 4	CCD-bearing protein	Berberine bridge enzyme	70%-75%
Phl p 5	Group 5 (Ribonuclease)	Ribonuclease	50%-95%
Minor specific allergens	-	-	-
Phl p 2	Group 2 (expansin-like protein)	Unknown	55%-65%
Phl p 3	Group 3 (expansin-like protein)	Unknown	60%
Phl p 6	Group 6	Unknown	44%-75%
Phl p 11	Ole e 1-like protein	Trypsin inhibitor	32%-43%
Cross-reactive allergens	-	-	-
Phl p 7	Polcalcin	Calcium-binding protein	7%-10%
Phl p 12	Profilin	Actin-binding protein	15%

Source: Mendy and Zeldin (2020).

Proteins and lipids contained in pollen were the main allergens, which helped to classify them based on species characteristics and functionality of compounds. These differences are conditioned by evolutionary adaptation, which influences allergic reactions in humans. For example, grass pollen of the genus *Phleum pratense (Timothy-grass)* and *Lolium perenne (*Perennial ryegrass), containing the allergens Phl p5 and Lol p5, respectively, has been studied as one of the most powerful triggers of allergic reactions affecting up to 90% of patients allergic to grass pollen (Hew *et al*., 2020).

The cross-reactivity between allergen proteins of different types of grasses was explained by the similarity of amino acid sequences and biochemical functionality. However, the reactivity between species such as *Festuca* and *Lolium* was unpredictable and depended on the prevalence and concentration of pollen (Hew *et al*., 2020). Not all species of the same genus showed the same allergenicity; for example, the cross-reactivity between *Festuca* and *Lolium* turned out to be lower than expected (Harding, Kinealy, and Franzese, 2021). The allergenic indices of grasses were based on plant height, perenniality, pollen count, and flowering duration (Suanno *et al*., 2021).

Manifestations and Risks of Allergic Conditions to Grass Pollen

The study by Susanto *et al*. (2022) revealed important aspects of the relationship between the effect of grass pollen at an early age and the risk of food allergy in infants. The effect of grass pollen on the child's body in the first week of life increases the risk of developing sensitivity to peanuts, which was expressed in an adjusted modified odds ratio (aMOR)=1.21. Pollen exposure at the age of 4-6 months is associated with an increased risk of egg allergy aMOR=1.02 and sensitisation to various foods aMOR=1.02. Exposure to grass pollen, especially, increases the chances of developing food allergies in infants if the mother had a history of food allergies. The study revealed the potential

effect of grass pollen on the development of food allergies in infants both in the prenatal period and in the first months of life.

The study by Lindqvist *et al*. (2024) of allergic rhinitis throughout 20 years was carried out in patients from childhood to adulthood. It involved 1,137 patients who filled out a questionnaire with the severity of symptoms of bronchial asthma and rhinitis, specific immunotherapy, and evaluation of IgE results for aeroallergens at the ages of 4, 8, 16, and 24 years. The symptoms considered in the study included sneezing, rhinorrhoea, nasal itching, nasal congestion, itchy eyes, and lacrimation on exposure to grass or birch pollen combined with IgE greater than 0.35 kDa to grass or birch. The prevalence of sensitisation to these allergens at the age of 4-16 years tended to increase from 12.6% to 33.7%. From the age of 16, this indicator stabilised and remained until the age of 24, amounting to 34.8%. The prevalence of allergic rhinitis symptoms also increased from 4 to 16 years old, which was 2.3% and 22.5%, respectively, followed by a gradual increase in the age of 16-24 years to 25.3%. The prevalence of allergic rhinitis with sensitisation to grasses increased from 1.9% in 4 years, 9.0% in 8 years, to 18.9% in 16 years, without a significant increase in the age group of 16-24 years, which was 20%. Bronchial asthma was registered in 13.3% of patients at 4 years old, 10.5% at 8 years old, 14.9% at 16 years old, and 14.5% at 24 years old. The percentage of patients who had a combination of asthma and allergic rhinitis was 36.4% at the age of 4 and 30.8% at the age of 24. It was also found that about 75% of children with allergic rhinitis to grass pollen at the ages of 4 and 8 years old noted a persistent form of the disease before the age of 24, and 30% developed bronchial allergic asthma. Increased risks of resistance were noted already at minimum IgE values. The highest remission rate of allergic rhinitis to pollen was found in patients aged 16 to 24 years, which accounted for 21.5% of cases, but a large number of participants remained sensitive. In this age period, there was also a slowdown in IgE levels, and the average annual incidence of allergic rhinitis decreased from 1.5% to 0.8% per year.

Another similar study by Westman *et al*. (2020) involved 763 participants. Allergic rhinitis to grass pollen was determined by the symptoms that occur in the upper respiratory system under the influence of grass pollen. The analysis showed that the frequency of sensitivity to any protein allergen of common timothy was higher than to timothy extract in all age groups. At the age of 4, sensitisation to Phl p molecules was 9.7%, compared with 6.8% to timothy extract; at the age of 8, these indicators were 28.4% and 15.3%, respectively; and at the age of 16, 37.1% versus 27.1%. The pooled odds ratio (OR) of developing late episodes of allergic rhinitis to grass pollen was increased in children aged 4 years who were sensitive to IgE reactivity to Phl p 1 (OR=4.9) and Phl p 4 (OR=6.9). The likelihood of symptoms of allergic rhinitis increased with age, with an increase in the number of allergen molecules. At the age of 4, the presence of 2 or more molecules predicted the disease with a probability of up to 78%, and the presence of 3 or more – up to 95%. A positive test for timothy extract predicted allergic rhinitis to grass pollen with a probability of up to 70%. Although the reported odds ratios suggest a notable association between early sensitisation to specific allergen molecules and the subsequent development of allergic rhinitis, it is important to interpret these findings with caution. Odds ratios reflect the strength of statistical association but do not inherently indicate clinical relevance unless supported by large-sample studies and effect size consistency across diverse populations. In the case of

small-sample cohorts or studies involving specific subgroups (e.g., children aged four), generalisability may be limited. Therefore, while the data indicate potential predictive biomarkers of allergic rhinitis, further large-scale prospective studies are required to validate these findings and confirm their practical utility in clinical settings.

In a systematic review, the effect of pollen on asthma exacerbations was analysed (Annesi-Maesano *et al*., 2023). It has been found that the influence of pollen can affect the worsening of asthma symptoms, especially in children. The highest correlation was found between asthma outbreaks and an increase in grass pollen concentration. In children under the age of 18, a large amount of grass pollen is associated with asthma exacerbations, hospitalization, and visits to emergency departments. In some children, the effect of grass pollen for 3 days may reduce lung function (Kashanskiĭ *et al*., 2008).

The study by Batra *et al*. (2022) focused on investigating the relationship between grass pollen levels and repeated hospitalisations of children in paediatric departments. The readmission rate was defined as repeated hospitalisation within 28 days after discharge. The total number of repeat hospitalisations increased significantly during the grass flowering season compared to other periods of the year (incidence rate ratio (IRR) 1.44). In children aged 2 to 5 years, this indicator was even higher (IRR 1.99). In the age group of 13-18 years, a non-linear relationship was observed between the pollen level on the same day and the number of readmissions, while significant effects were recorded at pollen levels from 110 to 256 grains/m³ ($p<0.01$). Grass pollen with a delay of 2 days also showed a non-linear relationship with the number of readmissions in general ($p=0.03$), especially in boys ($p=0.01$) and in young children (2-5 years, $p=0.02$; 6-12 years, $p<0.001$).

Thunderstorm asthma is a sharp deterioration in the condition of asthmatics, which occurs shortly after a thunderstorm. The study by Idrose *et al*. (2020) assessed whether grass pollen is a key factor in the development of thunderstorm asthma and determined whether the presence of fungi affects this relationship. An association was found between an increase in the concentration of grass pollen (with a delay of up to four days) and an increased risk of thunderstorm asthma. A positive association between the fungus and thunderstorm asthma has also been found. Fungal taxa varied depending on the time of measurements: before, during, or after the thunderstorm. No correlation was found between the effects of fungi on the occurrence of thunderstorm asthma associated with grass pollen. The main methods of prevention and treatment included optimising asthma control, increasing adherence to inhaled corticosteroids, treating seasonal allergic rhinitis, and informing patients about stormy days when the risk of asthma is increased (Chatelier *et al*., 2021). Individual approaches may include allergen-specific immunotherapy and biologics, which will reduce the severity of asthma symptoms.

The study by Gisler *et al*. (2022) considered the effect of pollen on the development of respiratory symptoms in infants and how factors such as manifestations of atopic dermatitis in the mother, the sex of the infant, and air pollution can change this relationship. It was found that plant pollen was able to increase the frequency of symptoms of the respiratory system during the day and at night for woody species, herbaceous species. There was no significant effect of maternal atopy or infant sex on

this relationship, but a complex cross-interaction between pollen levels and air pollution particles was found.

The study by Özdemir *et al*. (2023) assessed the incidence and manifestation of pollen and food allergy syndrome (PFAS) in patients over 18 years of age suffering from seasonal rhinitis. The study included 222 patients with the specified diagnosis, who were assessed for atopy using a standard skin test panel, including common extracts of aeroallergens. Of these, 14% of rhinitis patients (31 out of 222) reported the presence of PFAS. The most common symptoms of PFAS were isolated symptoms in the oropharynx (58.1%) and urticaria (51.6%) after meals. The main sensitising aeroallergen was grass pollen. Eggplant, walnut, kiwi, peach, and melon were often the most challenging foods.

Diagnosis and Treatment of Allergy to Grass Pollen

The study by Ørby *et al*. (2021) of the inhalation-controlled environment was aimed at assessing the allergenic reaction to isolated allergens or pollen extracts. Such experiments helped to reproduce the real inhalation load of allergens in the laboratory, which contributes to a more accurate assessment of the allergic reaction. Using a controlled environment reduces the influence of extraneous factors such as weather conditions or the concentration of allergens in the environment, which often complicates outdoor research (Fedoniuk *et al*., 2024; Yermukhanova *et al*., 2017). In experiments by Ørby *et al*. (2021), specific immune responses to individual pollen components of various plant species were investigated. These studies have provided important data on how different types of allergens affect sensitisation and allergic reactions, which helps to more accurately determine the allergenic profiles for each species. The results showed that specific allergens can cause varying degrees of allergic reaction in patients, depending on their immunological response to specific proteins contained in pollen. Standard pollen monitoring allowed medical professionals and researchers to collect data on pollen concentrations in the air, which contributed to the creation of predictive models (Kurganskiy *et al*., 2021). This data is used to warn people with allergies in advance about potential peak loads of allergens, which would allow them to take preventive measures. Monitoring methods included the collection and analysis of pollen in specific regions, followed by the transmission of information to the public. The forecasts are based on historical data and current meteorological conditions, which helps to more accurately determine the periods when the concentration of pollen will be greatest. This allowed people with pollen allergies to start medication promptly or limit outdoor exposure. Thus, the study by Kurganskiy *et al*. (2021) emphasises that regular pollen monitoring was a simple and effective method of preventing exacerbations of allergic reactions and improving the quality of life of people suffering from pollen allergies.

The diagnosis of allergic rhinitis to grass pollen has been investigated by Barreto *et al*. (2023). Several examinations were conducted for 72 patients, including a questionnaire, a skin test, and the determination of general and specific IgE. Throughout the season, patients noted symptoms, medication use, and general condition in an electronic diary using a visual analogue scale. After the grass flowering season, patients were tested for nasal provocation with the herbal extract. Patients with a positive test of nasal provocation to grass pollen accounted for 68.1%, compared with those who had a negative test, noted worse indicators on the visual analogue scale, more pronounced skin

test reactions and higher indicators of general and specific IgE, and increased specific activity to Timothy and Bermuda grass rPhl p 5 and nCyn d 1. All the results were evaluated, from which it was assumed that, based on the IgE index for Phl p 5 and Cyn d 1, the results of the analogue scale of symptoms, it was possible to predict the severity of nasal provocation to grass pollen. These data are of great importance in the diagnosis of an allergic condition to grass pollen.

Research data show that cross-reactivity between representatives of the grass subfamily *Pooideae*, in particular between *Festuca pratensis* (Meadow fescue) and *Phleum pratense* (Common timothy), may be less complete than previously thought (Harding, Kinealy, and Franzese, 2021). Of the 1,239 patients who tested positive for one type of grass, 38.6% tested positive only for *Festuca pratensis,* indicating a significant proportion of patients with sensitivity to this type of grass. A smaller number of cases, accounting for 27.6% of patients, tested positive only for *Phleum pratense*. Despite the lower percentage, these data confirm that *Phleum* remains an important allergen for the diagnosis of allergic rhinitis, but cannot be considered representative of the entire subfamily *Pooideae*. Only 33.7% of patients demonstrated positive results simultaneously for both types of grasses (*Festuca* and *Phleum*), indicating that cross-reactivity between these types of grasses may be incomplete. This study highlights the need to reconsider the approach to the diagnosis of allergies to grasses. Traditionally, testing is often done on a single species, *Phleum pratense*, which may miss sensitivity to other grasses such as *Festuca pratensis*. This indicates the need to expand the range of tests to include other plants to more accurately diagnose allergies.

In the study by Bostan *et al*. (2022), the relationship between allergy to timothy pollen (*Phleum pratense*) and sensitisation to cat allergens was investigated, and potential prognostic factors that could predict the development of sensitivity to feline allergens were identified. Among 383 patients with rhinitis, 55.6% were in the timothy allergy group, and in this group, the frequency of sensitisation to cats was 33.8%**,** which was characterised by higher values than the group without allergy to this plant (12.3%). This statistically significant difference ($p<0.001$) suggests a possible link between plant allergy and cat allergy. Despite the high incidence of cat sensitisation among patients with allergy to timothy, owning a cat did not turn out to be a significant point for starting the allergic process, since the difference between both groups was minor ($p=0.63$). This indicated that having a cat in the house was not necessarily associated with the development of cat allergies in patients with plant allergies. Cat ownership was a significant risk factor for sensitisation to cats with a risk factor of 23.07 (95% CI, 7.72-68.91), which confirms the association between constant exposure to feline allergens and an increased chance of sensitivity. Allergy to common timothy was also an important risk factor for sensitisation to cats, with a hazard ratio of 7.72 (95% CI, 3.16-18.86). This indicated that an allergy to grass can affect the immune system's response and increase the likelihood of feline allergy. The results suggest that an allergy to grass pollen may affect changes in the immune system towards activation of type 2 T helper cells and increased production of Ig E, which, in turn, may increase sensitivity to other allergens, such as feline ones.

The effectiveness of using serum cIdE and total IgE for the correct detection of pollen allergy, as well as the effect of cross-reactive carbohydrate determinants (CCD) on test

accuracy, was evaluated in the study by Yokoi *et al*. (2022). The levels of specific IgE against cedar pollen showed the highest accuracy in allergy screening, with an area under the curve of 0.87. Cypress pollen had 0.82, while grasses and ragweed showed lower values, 0.63 and 0.56, respectively. The influence of cross-reactive carbohydrate determinants led to false-positive results when measuring IgE. This particularly affected patients who tested positive for pollen allergy without being sensitised to specific allergens. CCDs can create false reactions in tests, which reduces the accuracy of diagnosis and requires additional attention when interpreting test results.

Prevention and Treatment of Allergic Conditions to Grass Pollen

In the fight against allergies, the WHO (2006) recommends avoiding the main risk factors for allergies, which include excessive air pollution. Preventive measures include mechanical drying of clothes to remove pollen and allergens that settle on fabrics after outdoor activities. In the experiments by Choi *et al*. (2020), tissue samples contaminated with pollen from various plants such as timothy, ragweed, birch, and Japanese cedar were used. The difference in pollen removal between dry and wet tissues after mechanical drying was estimated. Mechanical drying has shown high pollen removal efficiency — about 99% for both dry and wet samples. For dry tissues, the pollen removal coefficients ranged from 99.82% to 99.96%, depending on the type of pollen. Wet fabrics had lower efficiency, but also high results (from 96.3% to 98.83%). Allergens (e.g., Amb a 1 – ragweed, Crp j 1 – Japanese cedar, Bet v 1 – birch, Phl p 1 – timothy) were also effectively removed, especially from dry tissues (approximately 99%). For wet samples, the allergen removal efficiency was slightly lower, but still significant (from 95.23% to 98.11%). There was no statistically significant difference in the removal of pollen and allergens between dry and wet tissues, which confirms the high efficiency of mechanical drying.

Allergy treatment includes antihistamines, and more modern methods such as allergen immunotherapy, including sublingual immunotherapy (SLIT) and allergen injections (Hartmane *et al*., 2024). Immunotherapy can provide long-term protection, especially when using extracts of *Phleum pratense*, which has stimulated immunity against other moderate herbs through cross-reactivity.

The study by Marko and Pawliczak (2023) compared the efficacy and safety of various therapies for the treatment of allergic rhinitis, including oral antihistamines (AH), intranasal antihistamines (INAH), intranasal glucocorticosteroids (INCS), and subcutaneous (SCIT) and sublingual (SLIT) immunotherapy. Attention was focused on three key allergens that cause rhinitis: dust mites, grass pollen, and birch pollen (Halken *et al.*, 2017). The most effective treatment methods were the combined use of INCS and INAH in one device, and the separate use of INAH for allergy to grass pollen. In the treatment of symptoms caused by dust mites, INCS showed the best results.

Van Nunen *et al*. (2022) conducted a study, which showed that sublingual immunotherapy for grass pollen using an herbal tablet with 5 types of herbs is effective for patients with seasonal allergic rhinitis caused by grass pollen. The study focused on patients who were polysensitised to grass pollen in temperate and subtropical climates. The majority of patients (74.6%) were sensitive to several plants to subtropical and

moderate grass pollen, and only 23.8% were allergic to only one grass pollen. Despite this, all patients showed a significant improvement in the symptoms of allergic rhinitis during the SLIT treatment. Since the first pollen season, statistically significant improvements in symptoms have been observed in both mono-sensitised and poly-sensitised patients. The improvement reached 70-85% by the third season, which confirms the sustained effectiveness of therapy. Polysensitization to grass pollen did not affect the effectiveness of treatment.

The study by Vogelberg *et al*. (2020) was aimed at assessing patients' adherence to allergen-specific immunotherapy (AIT) using subcutaneous and sublingual immunotherapy. The study focused on patients with allergies to grass and tree pollen and assessed the effect of AIT on the need for drug therapy for the treatment of asthma and rhinitis. After two years, patients' adherence to SCIT was 60.1-61.8%, and after three years it decreased to 35.0-37.5%, regardless of the type of allergen. The commitment to the SLOT was significantly lower, amounting to 29.5-36.5% after two years and only 9.6-18.2% after three years. It is important to note that children showed greater adherence to therapy compared to adolescents and adults. Thus, SCIT in real clinical practice demonstrates higher adherence among patients and a significant reduction in the need for asthma and rhinitis medications compared to SLIT. While SLIT also reduces the consumption of medicines for rhinitis for both groups of allergens, its effect on asthma treatment is manifested only in case of allergy to grass pollen.

The study by González-Bravo *et al*. (2022) included a description of four patients over 65 years of age who were diagnosed with moderate seasonal allergic rhinoconjunctivitis and moderate asthma caused by grass pollen. Due to the severity of rhinoconjunctivitis symptoms and worsening asthma in the spring, they were prescribed the unmarked use of oral immunotherapy with grass pollen. All patients noted an improvement in the symptoms of rhinoconjunctivitis and asthma already in the first spring season, and the improvements persisted for two years of follow-up. No systemic adverse reactions were noted, except for temporary itching in the oral cavity in two patients, which passed on its own.

The study by Traina *et al*. (2021) involved 34 patients diagnosed with allergic rhinoconjunctivitis, with or without asthma. Patients underwent SCIT with pollen allergens of grass, birch, or mixed trees according to an accelerated induction scheme, including three injections (once a week), unlike the standard scheme, which provides five injections (also once a week). During the accelerated SCIT, none of the patients had any treatment-related side effects. Neither local reactions nor systemic pathological conditions of varying degrees were observed. The tolerability of the therapy was assessed as "very good" by both patients and attending physicians.

These data indicate that the prevention of grass pollen allergy requires an integrated approach, including not only environmental control, such as reducing exposure to areas with polluted air, but also socioeconomic and health system strategies. While standard pharmacotherapy using inhaled corticosteroids, antihistamines, and other symptomatic agents remains effective, access to specific immunotherapy (SCIT and SLIT) varies significantly depending on region and healthcare infrastructure. In Poland, for instance, disparities in healthcare delivery between urban and rural areas may limit access to

allergen immunotherapy, especially in regions with lower healthcare funding or fewer allergy specialists. Although studies like those by Vogelberg *et al*. (2020) and González-Bravo *et al*. (2022) demonstrate the efficacy of SCIT and SLIT, their implementation depends on sustained adherence, availability of trained personnel, and patients' socioeconomic conditions, all of which vary by region. Targeted urban health policies, such as subsidising immunotherapy or integrating allergy management into primary care, may be essential to ensure equitable access.

Moreover, while climate change is acknowledged as a key factor extending the pollen season and exacerbating allergy symptoms, its mechanistic contribution to allergenicity remains underexplored in many studies. Elevated atmospheric CO_2 concentrations, widely documented in IPCC Assessment Reports, have been shown to stimulate biomass production and increase allergenic protein content in pollen, particularly in grasses. This physiological response to environmental stressors suggests not only longer flowering seasons but also more potent pollen with higher sensitisation capacity, intensifying the health burden. In light of these findings, the inclusion of climate-adaptive public health interventions, such as early pollen season warnings and urban greening policies that limit highly allergenic plantings, becomes increasingly relevant. Future research and policymaking should therefore prioritise both the biological and systemic dimensions of pollen allergy management to ensure climate-resilient and socially equitable healthcare responses.

This study has certain limitations that should be acknowledged. Although the issue of low adherence to long-term allergen-specific immunotherapy is noted, the analysis does not explore in detail the multifactorial causes of non-compliance or propose targeted intervention strategies. Future research may benefit from a deeper examination of behavioural, socioeconomic, and healthcare system-related barriers to adherence. Additionally, while selected data from Poland provides a valuable regional perspective, the analysis would be strengthened by the inclusion of comparative cross-country insights and policy-oriented case studies that could contextualise the Polish experience within a broader European framework.

Conclusion

During the study, it was found that the most common allergens in Europe are grass pollen, birch, and ragweed. Among the manifestations that are characteristic of allergy to pollen of plants include sneezing, lacrimation, swelling of the nose and difficulty breathing through the nose, itching in the throat, nose and eyes, runny nose, feeling of soreness, weakness, drowsiness, decreased attention, and cough with shortness of breath or wheezing, headaches. The diagnoses that should be noted include allergic bronchial asthma, allergic rhinitis, and conjunctivitis. The most active allergens that lead to the development of an allergic condition include molecules of common timothy. The most significant allergen, which plays an important diagnostic role, is Phl p 1.

It was found that green spaces had a protective effect on the severity of allergic symptoms, provided that the density of allergenic plants was low. Air pollution can worsen the manifestations of allergy to grass pollen. In Poland, where urbanisation and air pollution are significant problems, this can hurt the development and worsen grass

pollen allergies. Thunderstorm asthma can pose a serious threat to people with pollen allergies, especially in the spring and summer, when grass pollen levels are especially high. In addition, grass pollen can increase the number of exacerbations of childhood bronchial asthma and cause repeated hospitalisations to paediatric departments. Immunotherapy with the use of herbal allergens remains the most important method of treating allergic rhinitis and asthma, which can improve the course of the disease and reduce the level of sensitisation. In Poland, where allergy to grass pollen is especially common, skin and sublingual immunotherapy can be used for long-term control of allergic symptoms. However, patient adherence to long-term therapy remains a problem, as in other countries. Policies to improve air quality and increase green spaces can be useful strategies to reduce the severity of allergic symptoms. Future studies should be conducted to more accurately determine the optimal conditions for minimising allergic reactions in the population.

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Authors' Declarations and Essential Ethical Compliances

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